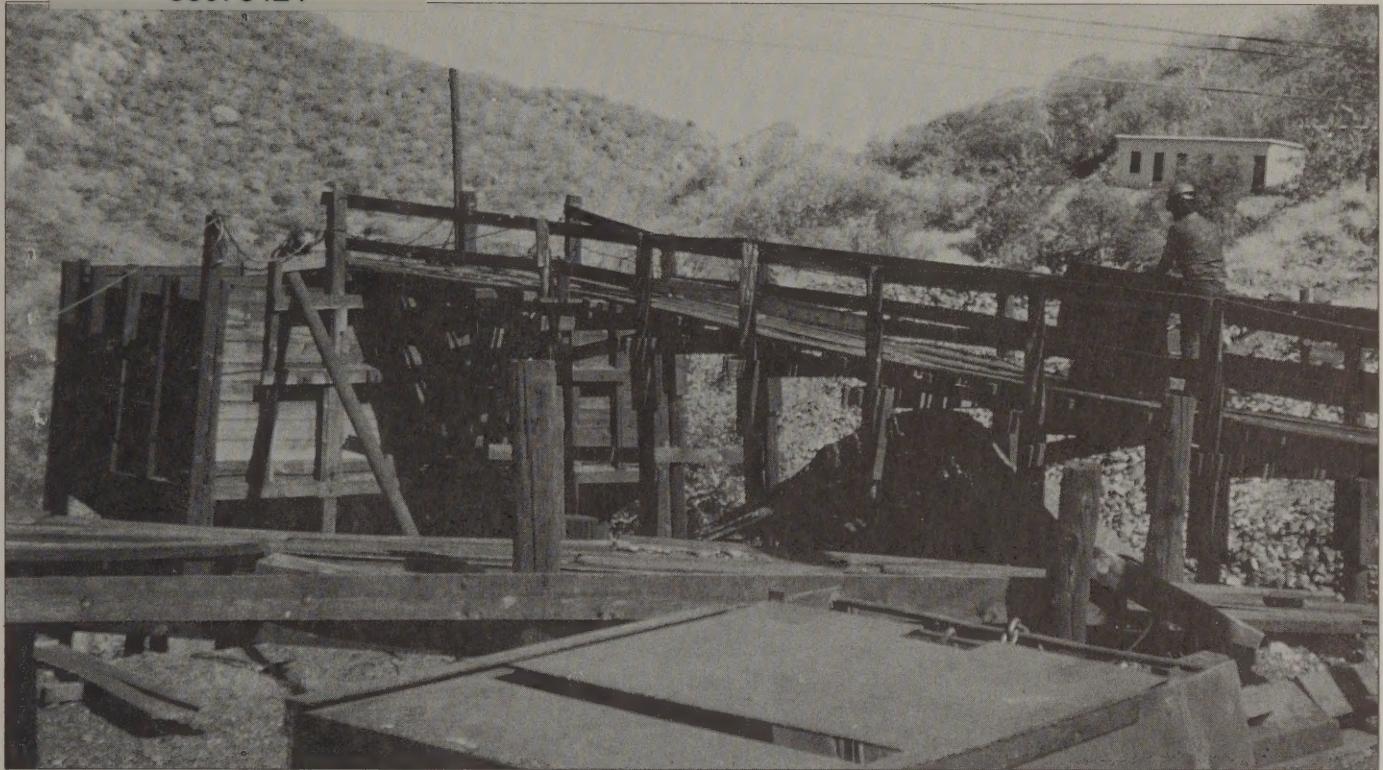


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ANNUAL REPORT



# GRAPHITE

By Harold A. Taylor, Jr.

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# GRAPHITE



U.S.  
DEPARTMENT  
OF THE  
INTERIOR

Manuel Lujan, Jr.  
Secretary



BUREAU  
OF  
MINES

T S Ary  
Director

October 1991

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# GRAPHITE

By Harold A. Taylor, Jr.

**Mr. Taylor, a physical scientist with 25 years of industry, Federal Government, and U.S. Bureau of Mines experience, has been the commodity specialist for graphite since 1980. Domestic survey data were prepared by William Field, mineral data assistant; and international data tables were prepared by Audrey Wilkes, international data coordinator.**

**A**morphous graphite was not mined domestically in 1990. Graphite supplies caught up with industrial demand and then exceeded it to a minor degree. Some prices of the major imported graphite increased from those of 1989, and some were unchanged. Production of manufactured graphite and graphite fibers decreased 7% and increased by 29%, respectively.

## DOMESTIC DATA COVERAGE

Domestic production data for synthetic graphite are developed by the U.S. Bureau of Mines from a voluntary survey of domestic producers. Of the 32 operations polled, 100% responded. This represented 100% of the total production data shown in table 5.

## BACKGROUND

### Definitions, Grades, and Specifications

Graphite, a soft crystalline form of carbon, has been called plumbago and

black lead. It crystallizes in a lamellar hexagonal system, has a gray to black metallic luster, and is greasy to the feel. It is anisotropic in its physical properties and has a weak plane of cleavage parallel to the lamellae.

The term "amorphous" when applied to graphite is a misnomer. The term "microcrystalline" is more descriptive. The definition of amorphous, as applied to graphite, has been further complicated by longstanding industrial application of the term to very fine particles of crystalline flake graphite that can be sold only for low-value use such as foundry facings. Fine-grained varieties of lump graphite that are easily reduced to fine particle size by grinding are called amorphous lump to distinguish them from the tough, platy, and acicular varieties, known as crystalline lump, that can be reduced in particle size only with extreme difficulty.

Crystalline flake graphite is well defined in paragraph 214 of the Tariff Act of 1930 as follows:

"The term crystalline flake means graphite, or plumbago, which occurs disseminated as a relatively thin flake throughout its containing rock, decomposed or not, and which may or has been separated there from by ordinary

crushing, pulverizing, screening, or mechanical concentration process, such flake being made up of a number of parallel laminae, which may be separated by mechanical means."

Under the foregoing definition, finely divided particles of crystalline flake graphite would be classified as crystalline graphite. The Court of Customs Appeals, however, has held that commercial designations and not scientific terms must govern classification, and when a commercial meaning differs from the technical meaning, the commercial designation must govern. Therefore, quantities of fine crystalline flake graphite are imported under the amorphous classification.

Sri Lankan lump graphite is classified as amorphous or crystalline. Each type is divided into a number of grades, depending on the size (such as lump, ranging from the size of walnuts to that of peas; chip, from that of peas to about that of wheat grains; and dust, finer than 60 mesh), graphitic carbon content, and degree of consolidation.

Amorphous graphite is graded primarily on graphitic carbon content. Commercial ore contains about 75% to 93% carbon, depending on the source.

Crystalline flake graphite from Madagascar is divided into two main grades,

TABLE 1  
SALIENT NATURAL GRAPHITE STATISTICS

		1986	1987	1988	1989	1990
United States:						
Production	metric tons	—	—	W	W	—
Apparent consumption	do.	31,784	31,634	42,799	50,867	W
Exports	do.	7,034	11,700	11,068	11,452	11,537
Value	thousands	\$3,416	\$6,218	\$5,815	\$7,421	\$9,481
Imports for consumption	metric tons	38,818	43,334	53,867	62,319	50,213
Value	thousands	\$15,758	\$17,654	\$23,238	\$33,707	\$35,222
World: Production	metric tons	624,718	648,156	660,168	648,827	660,600

<sup>c</sup> Estimated. <sup>r</sup> Revised. W Withheld to avoid disclosing company proprietary data.

"flake" (coarse flake) and "fines" (fine flake). Madagascan crucible flake must have a minimum of 85% graphitic carbon and be essentially all minus 20-plus 80 mesh in particle size. Other crystalline flake graphite is also graded according to graphitic carbon content and particle size.

Natural graphite is marketed in the form of crystalline graphite as flake, lump, chip, and dust and in the form of amorphous graphite in sizes from fine powder to lumps up to the size of walnuts. It is common practice to blend different graphite to obtain a product having certain desired physical and chemical properties. In many instances, the composition of these blends is retained as a trade secret.

## Geology-Resources

The three principal types of natural graphite—lump, amorphous, and crystalline flake—are based on physical characteristics that are the result of major differences in geologic origin and occurrence. A variety of silicate minerals is generally associated with graphite in the ore.

Lump graphite occurs as fissure-filled veins. It is typically massive, ranging in particle size from extremely fine grains (amorphous) to coarse, platy intergrowths of fibrous to acicular aggregates (crystalline). The origin of vein-type graphite deposits is believed to be hydrothermal.

Amorphous graphite is formed by metamorphism of coalbeds by nearby intrusive. Its purity depends on the purity of the original coalbeds. Amorphous graphite usually is associated with sandstones, shales, slates, and limestones.

Flake graphite commonly occurs disseminated in regionally metamorphosed sedimentary rocks, such as gneisses, schists, and marbles. It is believed that the graphite was formed under the same conditions that caused the metamorphism of the rocks—from carbon deposited with the sediments.

Although the flake graphite deposits of certain countries conform to this description, most of the commercial deposits that are exploited are the result of weathering of these metamorphic rocks, with the graphite being found in lateritic clays that have accumulated at the surface. Graphite, quartz, and

other resistant minerals have been freed by weathering of the feldspars, thus lessening the amount of crushing necessary before beneficiation.

World graphite reserves totaled 21.0 million tons. Detailed breakouts are given in the 1988 Minerals Yearbook chapter.

## Technology

**Mining.**—In Sri Lanka, lump graphite is mined underground from narrow, steeply dipping veins. The ore is mined principally by overhand stoping and filling, using temporary stulls when necessary to support the walls. Hand drilling is used in most stoping to achieve selective mining and to avoid unwanted fines and product contamination. Drills are used in developing headings. The ore is hauled by truck to the sorting and classification yard.

Amorphous graphite beds are usually mined underground. However, the beds are much thicker than those of amorphous lump and crystalline lump. The ore is drilled, blasted, hand loaded into cars, and hauled to the surface by conventional methods.

Flake graphite deposits have been mined by underground and surface methods. Underground deposits are usually unweathered and require drilling and blasting. Most surface mining is confined to the weathered part of the deposit, and normal excavating equipment such as power shovels, bulldozers, and rippers is used with a minimum of drilling and blasting. The ore is usually trucked to the mill.

**Milling.**—Sri Lankan amorphous and crystalline lump graphite is refined by hand cobbing and hand sorting and wiping lumps on wet burlap to remove fines. Light hand sorting and cleaning operations are done by women, while the heavier duties are performed by men.

Most amorphous graphite that requires beneficiation is not worth mining. Preparation for most uses requires grinding only, and coarse impurities are removed by screening or air separation methods.

Flake graphite from disseminated deposits must be concentrated to meet market requirements. Virtually every known concentrating device and combination of separating principles have been tried. The mineral has gained a

reputation of being difficult to concentrate, and probably in no other industry has such a large proportion of the mills failed to make commercial recoveries. Graphite actually is one of the easiest minerals to segregate into a rough concentrate, but one of the most difficult to refine.

Because of the premium placed on the mesh size of flake graphite, the problem in milling is one of grinding to free the graphite without reducing the flake size excessively. This is difficult because, during grinding, the graphite flakes are cut by quartz and other angular gangue minerals, thus reducing flake size rapidly. However, if most of the quartz and other angular minerals are removed, subsequent grinding will usually reduce the size of the remaining gangue, with little further reduction in the size of the flake.

Because graphite floats readily and does not require a collector froth, flotation has become the accepted method for beneficiating disseminated ores. The chief problem lies with depressing the gangue minerals. Relatively pure grains of quartz, mica, and other gangue minerals inadvertently become smeared with the soft, fine graphite, making them floatable and resulting in the necessity for repeated cleaning of the concentrates to attain high-grade products.

## Substitutes

Some interchange of the various types and grades of natural graphite and between manufactured and natural graphite takes place, but the degree is difficult to determine. Manufactured graphite does not compete with natural graphite in most uses because of its greater cost. Manufactured graphite is not substitutable for natural flake graphite in clay-bonded graphite crucibles, although some crucibles are machined from manufactured graphite for special uses. Calcined coke and other carbons are satisfactory substitutes for graphite for certain foundry core and mold washes and are used when they can compete in terms of price and supply. Other carbons with high purity can be used in batteries.

## Economic Factors

The price structure of graphite is quite complex because of the wide variety of products and the lack of stan-

dard market quotations. Prices quoted in trade journals are only a range negotiated between buyer and seller. Quotations are available in Industrial Minerals, Chemical Marketing Reporter, and the U.S. Bureau of Mines Minerals Yearbook. However, average declared import values per ton for amorphous and crystalline graphite have been available for years from the Bureau of the Census data.

The cost for domestically produced graphite from new mines would be much higher than that for graphite from the major foreign sources for the same type and purity. The high cost of production results from high labor costs and the low graphite content of the ore.

**Employment and Productivity.**—Production and marketable natural graphite requires little hand labor, except for the graphite mined in Sri Lanka. Even in areas of low-cost labor, mechanical methods are used to mine and concentrate flake graphite.

Because of the small size of the domestic natural graphite industry, no publishable employment data are available. Because there is only one small mine and the product is beneficiated and processed to a minimal extent, employment probably does not exceed 50. Much of the imported graphite requires grinding, perhaps further refining, mixing with other grades to meet consumer specifications, bagging, and shipping. The total number of persons engaged in these operations, including marketing, probably does not exceed 500.

**Tariffs.**—Duties on graphite items imported from most favored nations (MFN) are minimal. Graphite from the U.S.S.R. and certain other nations is subject to a higher duty.

**Taxes.**—Graphite producers are granted a 22% depletion allowance for tax purposes on domestic lump and amorphous and 14% on domestic flake and on foreign operations.

#### Operating Factors

Natural graphite is an inert nontoxic substance, and environmental requirements are limited to dust control and certain organic vapors arising from ingredients blended with it to manufacture products.

TABLE 2  
U.S. IMPORT DUTIES

Tariff item	HTS No.	Most favored nation (MFN) Jan. 1, 1991	Non-MFN Jan. 1, 1991
Crystalline flake, (not including flake dust)	2504.10.10	0.7 cents per kilogram <sup>1</sup>	3.6 cents per kilogram.
Other powder	2504.10.50	Free	10% ad valorem.
Other	2504.90.00	Free	10% ad valorem.

<sup>1</sup>Duty temporarily suspended.

TABLE 3  
U.S. GOVERNMENT STOCKPILE GOALS AND YEAREND STOCKS  
OF NATURAL GRAPHITE IN 1990, BY TYPE

(Metric tons)

Type	Goal	National stockpile inventory
Madagascar crystalline flake	12,880	15,655
Sri Lanka amorphous lump	5,715	4,934
Crystalline, other than Madagascar and Sri Lanka	1,750	1,754
Nonstockpile-grade, all types	—	846

Source: General Services Administration, Inventory of Stockpile Materials as of Dec. 31, 1990.

#### ANNUAL REVIEW

##### Legislation and Government Programs

No acquisitions or disposal of graphite from the strategic and critical materials stockpile occurred in 1990. New, smaller goals were implemented by notice in the June 26, 1990, Federal Register, as follows: 12,880 metric tons for Madagascar crystalline flake and 1,750 tons for crystalline graphite from other than Madagascar and Sri Lanka.

##### Production

United Minerals Co. suspended production of its amorphous graphitic material from its Montana mine in 1990. Output of manufactured graphite decreased 7% to about 252,000 tons at 30 plants, with a likelihood of some unreported production for in-house use. Production of all kinds of graphite fiber and cloth increased 29% to 3,774 tons.

Union Carbide Corp. has sold one-half of its wholly owned graphite and carbon subsidiary to Mitsubishi Corp. of Japan for \$232.5 million. The proceeds were used to retire part of the company's debt. Union Carbide's in-

tention was to strengthen its role as a supplier to the metals industry. According to the firm, graphite-carbon sales totaled \$802 million in 1989. The Mitsubishi sales force will be used to support the graphite and carbon business. This transaction involves four U.S. graphite electrode and product plants.

##### Consumption and Uses

Reported consumption of natural graphite decreased 8% to about 36,300 tons, according to a survey of more than 230 users. The three major uses of natural graphite were refractories, lubricants, and brakelinings, which together accounted for 67% of reported consumption.

Nonclay refractories represent two important uses categories of graphite. Standard refractory products, particularly gunning and ramming mixes, accounted for a sizable part of the demand in the past 5 years, mainly as amorphous graphite. Crucibles, shrouds, nozzles, stopper heads, and retorts, used in hot-metal processing operations such as the continuous casting of steel, use significant amounts of crystalline flake. Coarse flake graphite is preferred for crucibles and refractory associated items, but generally it is mixed with some fine crystalline material of lower

TABLE 4  
PRINCIPAL PRODUCERS OF SYNTHETIC GRAPHITE IN 1990

Company	Plant location	Product <sup>1</sup>
Akzo Fortafil Fibers Inc.	Rockwood, TN	High-modulus Fibers.
Amoco Performance Products	Greenville, SC	Cloth, high-modulus fibers.
Ashland Petroleum Co., Carbon Fibers Div.	Ashland, KY	High-modulus fibers.
BASF Structural Materials Inc.	Rock Hill, SC	Do.
Courtaulds Grafil Co.	Sacramento, CA	Do.
Fiber Materials, Inc.	Biddeford, ME	Other.
Fiber Technology Corp.	Provo, UT	
BF Goodrich Co., Engineered Systems Div., Super Temp Operation	Santa Fe Springs, CA	Other.
Great Lakes Carbon Corp.	Morganton, NC	Electrodes, unmachined shapes, motor brushes, other.
Do.	Niagara Falls, NY	Do.
Do.	Ozark, AR	Do.
Hercules Inc.	Salt Lake City, UT	High-modulus fibers.
HITCO Materials Group, British Petroleum Co. Ltd.	Gardena, CA	Cloth and high-modulus fibers.
National Electrical Carbon Co.	Fostoria, OH	Motor brushes, unmachined shapes, cloth.
NAC Carbon Products, Inc.	Punxsutawney, PA	Other.
Pfizer Minerals, Pigments & Metals Div.	Easton, PA	Do.
Polycarbon, Inc.	Valencia, CA	Cloth.
Showa Denko Carbon Inc.	Ridgeville, SC	Electrodes, other.
Sigri Carbon Corp.	Hickman, KY	
Stackpole Fibers Co., Inc.	Lowell, MA	High-modulus fibers.
Superior Graphite Co.	Russellville, AR	Electrodes.
Do.	Hopkinsville, KY	Other.
Textron Corp., Avco Specialty Materials Div.	Lowell, MA	High-modulus fibers.
The Carbon/Graphite Group Inc.	Niagara Falls, NY	Anodes, electrodes, unmachined shapes, motor brushes, refractories.
Do.	St. Mary's, PA	Do.
The Carborundum Co., Metallics Systems Div.	Sanborn, NY	Motor brushes, unmachined shapes, cloth.
The Stackpole Corp., Carbon Div.	St. Mary's, PA	Motor brushes and unmachined shapes.
UCAR Carbon Co.	Clarksburg, WV	Anodes, electrodes, unmachined shapes, crucibles and vessels, other.
Do.	Clarksville, TN	Do.
Do.	Columbia, TN	Do.
Do.	Yabucoa, PR	Do.

<sup>1</sup> Cloth includes low-modulus fibers; motor brushes include machined shapes; crucibles include vessels.

value. The newest important refractory use for graphite in steelmaking is in carbon magnesite brick, where large amounts of crystalline flake are now used.

Graphite is used in brake and clutch linings. More graphite is being used as the brake and clutch producers change over from asbestos. The graphite lubricates, transfers the heat of friction away from the part, and leads to a lower rate of wear. Graphite is more commonly used in heavier duty nonautomobile lining. Low-quality crystalline

flake and amorphous graphite are suitable for foundry facing use. The graphite is mixed with a small amount of clay, suspended in an adhesive material, and applied as a thin coating to mold surfaces to provide for clean and easy mold release of the metal castings.

Graphite is important as a lubricant and as an ingredient in special packings. When used as a lubricant, it can be a dry powder or mixed with oil or water. It is used with materials that must withstand extreme conditions, such as very high temperatures. Mate-

rial for this use must be free of abrasive-type impurities.

#### Prices

Natural graphite prices are often negotiated between the buyer and seller and are based on purity and other criteria. Therefore, published price quotations such as those in Industrial Minerals are given as a range of prices. Another source of information for graphite prices is the average customs value per ton of the different imported classes. These mainly represent ship-

ments of unprocessed graphite. A third source for natural graphite prices is the amount paid per ton at the point of consumption.

The price for crystalline graphite at the point of consumption—mostly crystalline flake, some crystalline dust, and a little lump graphite—decreased slightly to \$1,561 per ton from \$1,574 (revised) in 1989. The price for amorphous graphite (including small amounts of amorphous-synthetic graphite mixtures) decreased by 12% to \$684 per ton, from \$780 (revised) in 1989.

### Foreign Trade

The United States changed its tariff classification to the Harmonized Code on January 1, 1989. This has made the 1988 and 1990 import and export statistics somewhat noncomparable.

Total exports of natural graphite increased slightly. Exports of graphite electrodes totaled 84,602 tons valued at \$144.3 million, of which 33,235 tons (\$34.5 million) went to Canada, 7,552 tons (\$12.5 million) to Brazil, 5,964 tons (\$15.8 million) to Japan, 3,517 tons (\$7.7 million) to Venezuela, and

the balance to other destinations.

Imports of natural graphite decreased 20% from those of 1989. Imports of natural graphite from Canada and Madagascar rose substantially, while imports from Brazil, the Republic of Korea, and Mexico decreased significantly.

### World Review

The current year has begun the sorting out of last year's confusion about whether or not the Chinese were really exporting less and about which Canadian deposits would actually be devel-

TABLE 5  
U.S. PRODUCTION OF SYNTHETIC GRAPHITE, BY USE

Use	1989		1990	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
<b>Products:</b>				
Anodes	6,196	\$18,144	3,549	\$11,259
Cloth and fibers (low-modulus)	377	34,846	380	29,232
Crucibles, vessels, refractories	W	W	( <sup>1</sup> )	( <sup>1</sup> )
Electric motor brushes and machined shapes	W	W	3,139	21,902
Electrodes	188,264	379,196	169,798	363,319
High-modulus fibers	2,538	128,603	3,394	181,138
Unmachined graphite shapes	4,584	27,297	4,413	33,622
Other	6,201	<sup>2</sup> 90,008	3,130	78,044
Total	208,160	678,094	187,803	718,516
Synthetic graphite powder and scrap	62,259	28,574	63,984	33,605
<b>Grand total</b>	<b>270,419</b>	<b>706,668</b>	<b>251,787</b>	<b>752,121</b>

W Withheld to avoid disclosing company proprietary data; included with "Other."

<sup>1</sup>Crucibles, vessels, and refractories end products included in "Other" products category.

TABLE 6  
U.S. PRODUCTION OF GRAPHITE FIBERS

Year	Cloth and low-modulus fibers		High-modulus fibers		Total	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1980	153	\$11,254	278	\$17,379	431	\$28,633
1981	196	15,293	371	21,759	567	37,052
1982	192	17,706	549	30,091	741	47,797
1983	171	14,217	670	33,854	841	48,071
1984	202	17,979	1,052	56,436	1,254	74,415
1985	287	27,235	1,439	84,743	1,726	111,978
1986	149	17,895	1,373	76,622	1,522	94,517
1987	231	23,706	1,583	84,559	1,814	108,265
1988	239	28,228	2,176	117,754	2,415	145,982
1989	377	34,846	2,538	128,603	2,915	163,449
1990	380	29,232	3,394	181,138	3,774	210,370

TABLE 7  
U.S. CONSUMPTION OF NATURAL GRAPHITE, BY USE

Use	Crystalline		Amorphous <sup>1</sup>		Total <sup>2</sup>	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1988: <sup>3</sup>	<sup>r</sup> 18,897	<sup>r</sup> \$23,871	<sup>r</sup> 17,708	<sup>r</sup> \$12,978	<sup>r</sup> 36,605	<sup>r</sup> \$36,848
1989:						
Batteries	W	W	W	W	1,243	1,924
Brake linings	2,281	2,436	2,427	5,450	4,708	7,886
Carbon products <sup>4</sup>	340	886	167	242	507	1,128
Crucibles, retorts, stoppers, sleeves, nozzles	W	W	W	W	1,497	1,697
Foundries <sup>5</sup>	408	481	4,847	1,412	5,255	1,893
Lubricants <sup>6</sup>	3,391	5,033	3,125	1,068	6,516	6,101
Pencils	<sup>r</sup> 1,510	1,876	248	150	<sup>r</sup> 1,758	2,026
Powdered metals	1,401	2,551	58	111	1,459	2,662
Refractories	W	W	W	W	<sup>r</sup> 12,599	<sup>r</sup> 11,985
Rubber	72	108	406	314	478	422
Steelmaking	218	122	1,035	484	1,253	606
Other <sup>7</sup>	2,108	7,542	189	284	2,297	7,826
Withheld uses	<sup>r</sup> 7,516	<sup>r</sup> 9,260	7,823	6,346	—	—
Total	<sup>r</sup> 19,245	<sup>r</sup> 30,295	<sup>r</sup> 20,325	<sup>r</sup> 15,861	<sup>r</sup> 39,570	<sup>r</sup> 46,156
1990:						
Batteries	W	W	W	W	319	505
Brake linings	1,520	2,195	3,808	4,331	5,328	6,526
Carbon products <sup>4</sup>	243	647	114	142	358	789
Crucibles, retorts, stoppers, sleeves, nozzles	W	W	W	W	1,391	1,716
Foundries <sup>5</sup>	825	878	3,348	1,024	4,174	1,902
Lubricants <sup>6</sup>	3,999	6,326	3,540	1,397	7,539	7,723
Pencils	964	1,339	237	128	1,201	1,467
Powdered metals	1,278	2,691	37	66	1,315	2,757
Refractories	4,024	5,823	7,610	5,594	11,634	11,417
Rubber	W	W	W	W	421	329
Steelmaking	W	W	W	W	1,174	657
Other <sup>7</sup>	736	1,845	744	740	1,480	2,585
Withheld uses	1,839	2,333	1,467	874	—	—
Total <sup>2</sup>	15,428	24,077	20,905	14,296	36,334	38,373

<sup>r</sup> Revised. W Withheld to avoid disclosing company proprietary data; included with "Withheld uses."

<sup>1</sup> Includes mixtures of natural and manufactured graphite.

<sup>2</sup> Data may not add to totals shown because of independent rounding.

<sup>3</sup> Revision reflects a data correction in the refractories and other use categories.

<sup>4</sup> Includes bearings and carbon brushes.

<sup>5</sup> Includes foundry facings.

<sup>6</sup> Includes ammunition, packings, and seed coating.

<sup>7</sup> Includes paints and polishes, antiknock and other compounds, soldering and/or welding, electrical and electronic products, mechanical products, magnetic tape, small packages, industrial diamonds, and drilling mud.

oped. Demand for graphite in the United States was only slightly changed from that of 1989. Graphite moved into worldwide oversupply about midyear, but not in a major way. Prices were generally little changed. Norwegian production reached a much higher level in 1990. The Brazilian producers shelved plans for a major expansion of output, as did the Mexican companies involved

with crystalline flake. Mexican output of crystalline flake has not reflected even a previous doubling of capacity. The flurry of Canadian activity that continued to be reported seemed less likely to result in many new producers. The count of Canadian producers may level out at three or even fewer. China continues to be the major force in the market; its reported demise in the press

has been much exaggerated. Graphite in small quantities began to appear from Eastern Europe, primarily in Western European markets. The oversupply seems likely to worsen in 1991 as many consumers draw down their inventories. These inventories are frequently huge. Imports of graphite will drop very significantly. The prices of graphite are likely to drop significantly in

TABLE 8  
REPRESENTATIVE YEAREND GRAPHITE PRICES  
(Per metric ton)

	1989	1990
<b>Industrial Minerals:</b>		
Crystalline large flake, 85% to 90% carbon	\$820-\$1,300	\$820-\$1,300
Crystalline medium flake, 85% to 90% carbon	770- 1,120	770- 1,120
Crystalline small flake, 80% to 90% carbon	540- 900	540- 900
Powder (200 mesh), 95% to 97% carbon	770- 1,000	770- 1,000
Powder (200 mesh), 97% to 99% carbon	1,000- 1,300	1,000- 1,300
Amorphous powder, 80% to 85% carbon	220- 440	220- 440
<b>Customs value, at foreign ports:</b>		
Flake	913	935
Lump and chip, Sri Lankan	1,027	1,216
Amorphous, Mexican	114	116

<sup>1</sup>Revised.

Source: Industrial Minerals, No. 267, Dec. 1989, p. 82, and No. 279, Dec. 1990, p. 78.

TABLE 9

INDEXES OF UNIT VALUE OF  
GRAPHITE FIBER PRODUCED IN  
THE UNITED STATES<sup>1</sup>

(1973 = 100)

Year	Cloth and low-modulus fibers	High-modulus fibers
1979	114	56
1980	125	50
1981	129	46
1982	146	48
1983	129	45
1984	146	43
1985	149	50
1986	176	51
1987	153	50
1988	179	57
1989	164	52
1990	166	50

<sup>1</sup>The indexes were calculated from company data most representative of the industry and are not based solely on data shown in table 5.

TABLE 10  
U.S. EXPORTS OF NATURAL AND ARTIFICIAL GRAPHITE, BY COUNTRY

Country	Natural <sup>1</sup>		Artificial <sup>2</sup>		Total	
	Quantity (metric tons)	Value <sup>3</sup>	Quantity (metric tons)	Value <sup>3</sup>	Quantity (metric tons)	Value
<b>1989:</b>						
Brazil	8	\$17,452	885	\$1,324,786	893	\$1,342,238
Canada	5,936	3,032,576	14,295	4,964,881	20,231	7,997,457
Germany, Federal Republic of	156	72,316	1,860	848,464	2,016	920,780
Italy	102	211,966	268	261,984	370	473,950
Japan	572	691,249	1,905	2,734,937	2,477	3,426,186
Mexico	2,382	1,203,060	1,176	656,173	3,558	1,859,233
United Kingdom	448	189,271	3,777	2,485,322	4,225	2,674,593
Venezuela	411	686,777	90	79,166	501	765,943
Other	1,437	1,316,130	13,021	12,610,802	14,458	13,926,932
Total	11,452	7,420,797	37,277	25,966,515	48,729	33,387,312
<b>1990:</b>						
Brazil	332	800,456	1,188	2,442,945	1,520	3,243,401
Canada	3,769	2,394,059	16,690	7,262,105	20,460	9,656,164
Germany, Federal Republic of	542	560,828	1,070	669,536	1,612	1,230,364
Italy	86	259,254	271	242,728	357	501,982
Japan	556	744,063	1,588	4,977,240	2,144	5,721,303
Mexico	2,566	1,542,476	1,528	793,269	4,094	2,335,745
United Kingdom	365	349,342	2,563	1,538,004	2,928	1,887,346
Venezuela	914	750,788	398	537,539	1,312	1,288,327
Other	2,407	2,080,067	7,789	13,161,557	10,195	15,241,624
Total	11,537	9,481,333	33,085	31,624,923	44,622	41,106,256

<sup>1</sup>Amorphous, crystalline flake, lump or chip, and natural, not elsewhere classified. HTS Nos. 2504.10.0000 and 2504.90.0000.

<sup>2</sup>Includes artificial graphite and colloidal or semi-colloidal graphite. HTS Nos. 3801.10.0000 and 3801.20.0000.

<sup>3</sup>Customs value.

Source: Bureau of the Census.

TABLE 11  
U.S. IMPORTS FOR CONSUMPTION OF NATURAL GRAPHITE, BY COUNTRY

Country	Crystalline flake		Lump or chippy dust		Other natural crude and refined		Amorphous		Total	
	Quantity (metric tons)	Value <sup>1</sup> (thou-sands)	Quantity (metric tons)	Value <sup>1</sup> (thou-sands)	Quantity (metric tons)	Value <sup>1</sup> (thou-sands)	Quantity (metric tons)	Value <sup>1</sup> (thou-sands)	Quantity (metric tons)	Value <sup>1</sup> (thou-sands)
1988	8,249	\$6,120	2,819	\$2,376	23,676	\$13,625	19,123	\$1,117	53,867	\$23,238
1989:										
Austria	—	—	—	—	—	—	—	—	—	—
Belgium-Luxembourg	—	—	—	—	50	12	—	—	50	12
Brazil	2,613	2,937	—	—	2,935	3,018	—	—	5,548	5,955
Canada	r 3,144	r 3,135	—	—	r 2,261	r 1,784	—	—	5,405	4,919
China	2,995	2,047	—	—	12,504	7,906	1,090	995	16,589	10,948
France	—	—	—	—	50	196	—	—	50	196
Germany, Federal Republic of	38	48	—	—	182	479	—	—	220	527
Hong Kong	—	—	—	—	—	—	220	43	220	43
India	36	45	—	—	431	417	—	—	467	462
Japan	46	161	—	—	411	1,646	—	—	457	1,807
Korea, Republic of	—	—	—	—	—	—	7,275	380	7,275	380
Madagascar	r 2,294	r 1,822	—	—	r 2,368	r 1,818	—	—	4,662	3,640
Mexico	71	43	—	—	1,704	229	17,073	1,939	18,848	2,211
Netherlands	—	—	—	—	22	404	—	—	22	404
South Africa, Republic of	—	—	—	—	58	66	—	—	58	66
Sri Lanka	—	—	675	693	—	—	—	—	675	693
Switzerland	—	—	—	—	66	75	—	—	66	75
United Kingdom	—	—	—	—	1	6	—	—	1	6
Zimbabwe	685	643	—	—	1,018	697	—	—	1,703	1,340
Other	—	—	—	—	3	23	—	—	3	23
Total	r 11,922	r 10,881	675	693	r 24,064	r 18,776	25,658	3,357	62,319	33,707
1990:										
Austria	40	20	—	—	—	—	—	—	40	20
Belgium-Luxembourg	—	—	—	—	2	41	—	—	2	41
Brazil	1,455	1,996	—	—	213	307	—	—	1,668	2,303
Canada	5,162	5,038	—	—	4,449	4,068	—	—	9,611	9,106
China	10,047	6,628	—	—	5,036	3,409	1,615	264	16,698	10,301
France	—	—	—	—	15	147	—	—	15	147
Germany, Federal Republic of	276	721	—	—	7	65	—	—	283	786
Hong Kong	—	—	—	—	—	—	732	69	732	69
India	117	102	—	—	180	213	—	—	297	315
Japan	884	1,120	—	—	20	177	—	—	904	1,297
Madagascar	2,763	2,965	—	—	2,536	2,517	—	—	5,299	5,482
Mexico	40	10	—	—	1,567	997	10,570	1,224	12,177	2,231
South Africa, Republic of	100	59	—	—	—	—	—	—	100	59
Sri Lanka	—	—	565	687	—	—	—	—	565	687
Switzerland	—	—	—	—	289	50	—	—	289	50
United Kingdom	102	43	—	—	—	—	—	—	102	43
Zimbabwe	1,281	1,111	—	—	—	—	—	—	1,281	1,111
Other	141	1,143	—	—	9	31	—	—	150	1,174
Total	22,408	20,956	565	687	14,323	12,022	12,917	1,557	50,213	35,222

<sup>r</sup>Revised.

<sup>1</sup>Customs values.

Source: Bureau of the Census.

almost all instances.

**Canada.**—Mineraux Industrielle de Refractaire et Ceramique, a subsidiary of Imetal S.A., acquired a 25% share, worth \$5 million, of Stratmin Inc., Canada's principal producer of graphite.

TABLE 12

**U.S. IMPORTS FOR CONSUMPTION OF GRAPHITE ELECTRODES, BY COUNTRY<sup>1</sup>**

Country	Quantity (metric tons)	Graphite electrodes <sup>2</sup> Value <sup>3</sup> (thousands)
1989:		
Belgium	306	\$542
Brazil	1,289	503
Canada	6,130	6,277
China	526	831
France	1,387	1,367
Germany, Federal Republic of	2,758	4,082
Italy	5,931	9,747
Japan	4,889	7,807
Mexico	11,333	14,122
Spain	525	985
Sweden	—	5
Switzerland	55	105
Taiwan	4	14
United Kingdom	588	928
Other	669	874
Total	36,390	48,189
1990:		
Belgium	1,096	2,226
Canada	1,975	2,422
China	217	328
France	331	863
Germany, Federal Republic of	5,558	9,177
Italy	8,316	15,016
Japan	6,817	13,966
Mexico	12,298	16,132
Spain	626	1,228
Sweden	1	65
Switzerland	72	135
United Kingdom	537	992
Other	473	949
Total	38,317	63,499

<sup>1</sup>The artificial graphite imports category was reported through 1989. However, the category has been excluded from this table due to substantial delays in obtaining complete data for accurate comparison and reporting in the current period.

<sup>2</sup>Electric furnace electrodes; HTS No. 8545.11.0000.

<sup>3</sup>Customs values.

Source: Bureau of the Census.

This firm will become the exclusive agent for Stratmin's graphite product in Europe. The graphite will complement its present product line of refractory-related minerals such as andalusite and various clays.

A paper describing the Lac Knife graphite deposit of Societe d'Exploration Miniere Mazaring Inc. in detail was presented at the Ninth Industrial Minerals International Congress and later published in a journal. The paper covers the history, regional geology, geology and mineralogy of the deposit, reserves, proposed mining method, mine planning, ore beneficiation, environmental aspects, and the volume and specifications of the product.<sup>1</sup> Cambior Inc. intended to sign a joint-venture agreement with Mazarin to bring the deposit into production.

Cal Graphite Corp. operated at a very low level after a delayed fall start-up. The schedule was delayed by a waste disposal permit problem and by a decision to change the size of some major equipment items.

Global Graphite Group Ltd. has opened a high-purity and exfoliated graphite production facility in Anjou, Province of Quebec. The final capacity of the production line will be about 3,000 tons per year. The high-purity product was expected to contain 99% plus graphite and was to be made by acid leaching from Canadian and Brazilian feedstock. The exfoliated graphite was to be converted into graphite sheet, which can be sold for use in high-performance gaskets and seals. The high-purity product can be used in lubricants, batteries, ceramics, and certain refractories. Almost all of the product will be exported.

**China.**—According to the Yearbook of Iron and Steel Industry of China, Chinese production of graphite electrodes was 191,100 tons in 1988, 124,300 tons in 1987, and 99,800 tons in 1986. Production was 95,800 tons in 1985, 76,200 tons in 1980, 68,400 tons in 1975, and 32,800 tons in 1970.

**Sweden.**—The state mining Property Commission ordered the exploration of a crystalline flake graphite deposit at Kringeltjarn Lake, near Edsbyn, about 100 kilometers northwest of Gavle. After some graphite-rich boulders were found, detailed geophysical surveys and trenching began in 1985. Ore reserves

were delineated by extensive diamond drilling. Beneficiation studies and some pilot plant recovery have been done. Proven ore reserves are stated to be 1 million tons averaging 11% C plus 0.6 million tons of finer flake averaging 6% C on the eastern side of the deposit. The beneficiation studies indicated it would be possible to get a 90% recovery of two products, about one-half the tonnage a fine crystalline flake running 98% C and 40% of the tonnage a medium crystalline flake running 87% C. A joint-venture partner is now being sought to participate in a feasibility study.<sup>2</sup>

**Vietnam.**—A review of the current Vietnamese industrial mineral situation in a prominent Western publication comprehensively covered graphite. The size of Vietnamese graphite production is only moderate and comes from two areas. The northernmost and larger is north of Hanoi near Lao Cai and the Chinese border, and the other is 80 kilometers south of Danang. All of the graphite deposits seem to be distributed along the Red River Thrust Belt and found in schist or gneisses. The great majority of the graphite, if not all, is crystalline flake or crystalline dust. The largest and best known ore thickness is up to 35 meters and content ranging from 5% to 12% C. Vietnamese sources estimate that the six main ore bodies may contain a total of 2.5 million tons of graphite.<sup>3</sup>

## OUTLOOK

Projected demand for crystalline flake graphite totaled 23,000 tons for 1995 and 25,000 tons for the year 2000. Demand for other graphite, mostly amorphous, totaled 15,000 tons for 1995 and 13,000 tons for the year 2000. This relatively slow growth rate reflects the maturity of the market, mostly in refractories, and particularly in carbon-magnesite brick. Supply is likely to be abundant as the oversupply worsens.

<sup>1</sup>Bonneau, J., and R. Raby. The Lac Knife Graphite Deposit. Min. Mag., v. 163, No. 1, July 1990, pp. 12-18.

<sup>2</sup>Russell, A. The Swedish Minerals Industry. Ind. Miner. (London), No. 271, Apr. 1990, p. 51.

<sup>3</sup>Premoli, C. Industrial Minerals of Vietnam. Ind. Miner. (London), No. 274, July 1990, p. 65.

## OTHER SOURCES OF INFORMATION

### U.S. Bureau of Mines Publications

Graphite. Ch. in Mineral Commodity Summaries, annual.

Graphite. Ch. in Minerals Yearbook, annual.

Graphite. Reported annually in Mineral Industry Surveys.

### Other Sources

Chemical Week.

European Chemical News.

Industrial Minerals (London).

Materials Engineering.

Wall Street Journal.

TABLE 13

## GRAPHITE: WORLD PRODUCTION, BY COUNTRY<sup>1</sup>

(Metric tons)

Country <sup>2</sup>	1986	1987	1988	1989	1990 <sup>c</sup>
Argentina	40	216	24	r 100	100
Austria	36,167	39,391	7,577	r 15,307	17,500
Brazil (marketable) <sup>3</sup>	28,586	31,404	r 34,520	r 31,700	32,000
Burma <sup>4</sup>	722	—	—	—	—
China <sup>e</sup>	185,000	185,000	200,000	200,000	200,000
Czechoslovakia <sup>e</sup>	<sup>d</sup> 25,254	r 25,000	25,000	25,000	25,000
Germany, Federal Republic of	13,233	9,891	r 9,666	7,000	8,000
India (mine) <sup>6</sup>	38,412	42,589	r 57,325	r 47,731	50,000
Korea, North <sup>e</sup>	25,000	25,000	25,000	r 35,000	35,000
Korea, Republic of:					
Amorphous	96,577	106,507	107,767	r 100,282	100,000
Crystalline flake	641	838	678	r 1,186	1,000
Madagascar	16,187	13,169	14,106	r 15,863	16,000
Mexico:					
Amorphous	r 36,018	36,674	r 47,871	r 38,304	35,000
Crystalline flake	1,838	1,787	1,735	r 1,942	2,000
Norway	—	—	—	r 1,800	5,000
Romania <sup>e</sup>	12,000	12,000	12,000	10,000	20,000
Sri Lanka	7,453	9,400	8,547	4,163	4,000
Turkey (mine)	3,586	11,760	r 12,911	r 11,302	12,000
U.S.S.R. <sup>e</sup>	83,000	84,000	84,000	84,000	80,000
United States	—	—	W	W	—
Zimbabwe	15,004	13,530	11,441	r 18,147	18,000
Total	624,718	648,156	r 660,168	r 648,827	660,600

<sup>c</sup> Estimated. <sup>r</sup> Revised. W Withheld to avoid disclosing company proprietary data.

<sup>d</sup> Table includes data available through May 9, 1991.

<sup>2</sup> In addition to the countries listed, Canada produced graphite during the period covered by this table but output is unreported.

<sup>3</sup> Does not include the following quantities sold directly without beneficiation, in metric tons: 1985—16,425; 1986—19,074; 1987—10,505; 1988—18,269 (revised estimated); and 1989—20,000 (estimated).

<sup>4</sup> Data are for fiscal year beginning Apr. 1 of that stated.

<sup>5</sup> Reported figure.

<sup>6</sup> Indian marketable production is 10% to 20% of mine production.

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